

QCD dijet analyses

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Data sample

► Sample properties:

- reconstructed with p14.03.xx, p14.05.xx and p14.06.xx
- jet triggers: JT_25TT_NG, JT_45TT, JT_65TT, JT_95TT
- trigger lists: v8.20 — v12.xx
- bad data criteria:
 - run marked as BAD in Run Quality DB (CFT, SMT, Cal, Jet/MET)
 - trigger lists: v9.30 (L2 problems), v10.01 — v10.02 (L1 problems)
 - very short run (< 15 min.)
 - LBNs with “ring of fire” problem
 - runs with high average number of “bad” jets
- integrated luminosity: $\mathcal{L} = 143 \text{ pb}^{-1}$ (after all selections)



Dijet event selection

► Selection criteria:

- ▶ at least 2 jets (RunII cone $R = 0.7$)
- ▶ cut on primary vertex ($\varepsilon \approx 77 - 82\%$):
 - at least 3 tracks pointing to the primary vertex
 - $|Z_{PVtx}| < 50$ cm
- ▶ $ME_T < 0.7 \cdot P_T^{\text{leading jet}}$ ($\varepsilon \approx 100\%$)
- ▶ 2 leading jets pass new Jet ID cuts ($\varepsilon \approx 99\%$)

► Changes in jet ID cuts:

- ▶ jet confirmation from L1 ($\varepsilon \approx 97 - 99\%$):
 - L1SET – scalar transverse energy computed from the L1 calorimeter towers in the $R = 0.5$ cone in the jet direction
 - $L1SET < 0.4 \cdot P_T^{\text{jet}} \cdot (1 - \text{CHF})$ OR $L1SET > 80$ GeV
 - in ICD region, only 20% of the jet P_T is required

► Only central jets:

- ▶ $|\eta_{J1}|, |\eta_{J2}| < 0.5$



Dijet mass measurement

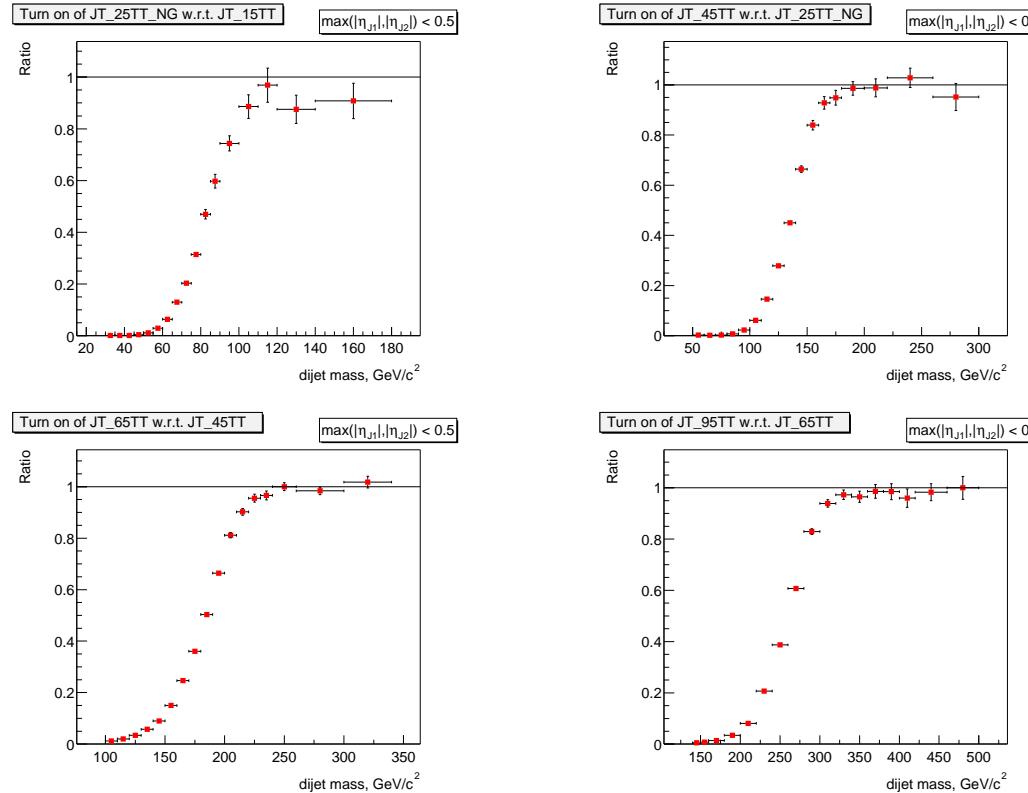
- ▶ probe of
 - ▶ QCD
 - ▶ proton structure at large x
 - ▶ hunting for resonances
 - ▶ quark compositeness

??? Figure with σ RunI and σ RunII ???

- ▶ master formula:

$$\left\langle \frac{d\sigma}{dM_{JJ}dy} \right\rangle = \frac{N_{evt}}{L} \cdot \frac{C_{unsmear}}{\varepsilon_{eff}} \cdot \frac{1}{\Delta M_{JJ}\Delta y}$$

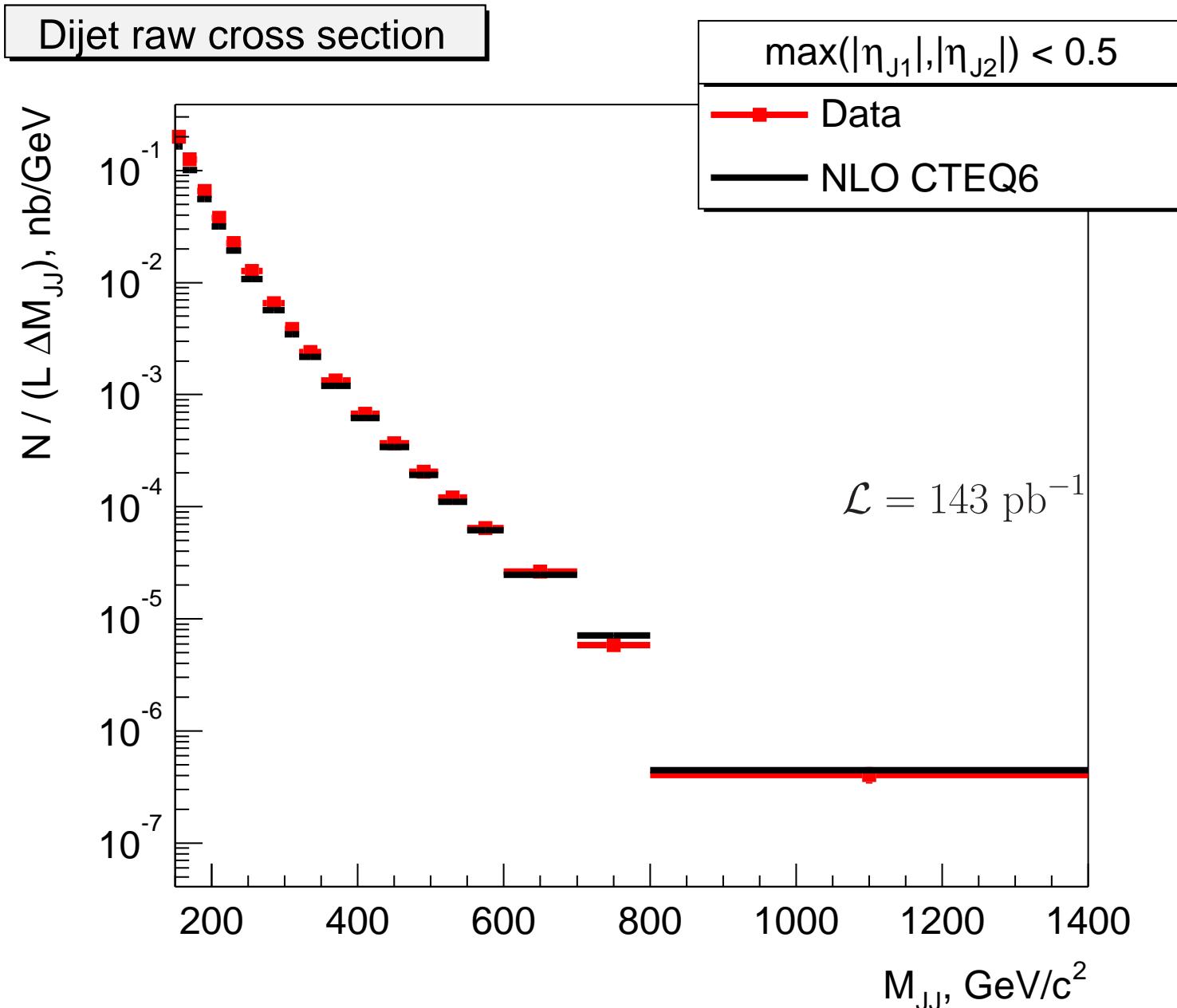
- ▶ relative turn-on curves
- ▶ ratio of the dijet mass spectra (JES applied)



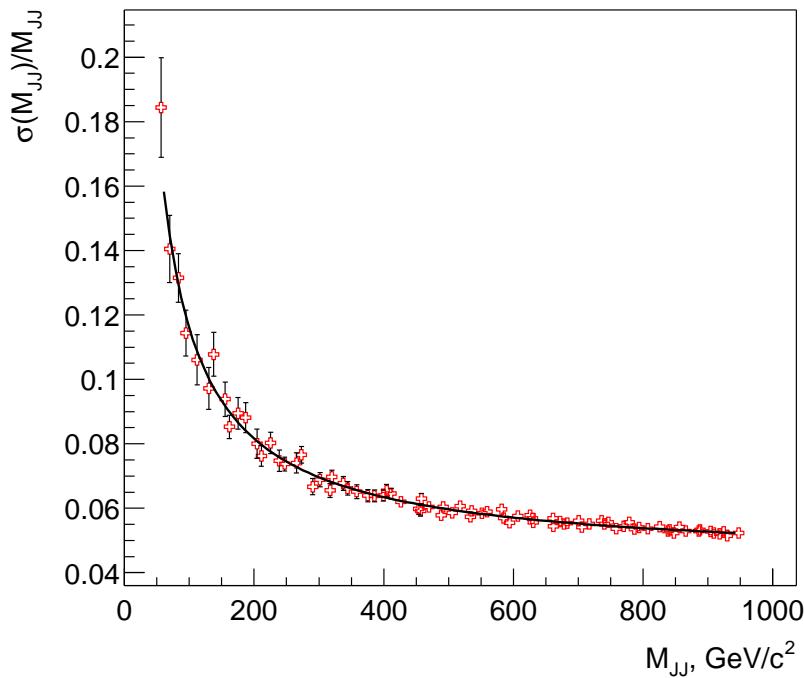
Trigger	JT_25TT_NG	JT_45TT	JT_65TT	JT_95TT
dijet mass, GeV/c ²	150.0	180.0	270.0	350.0



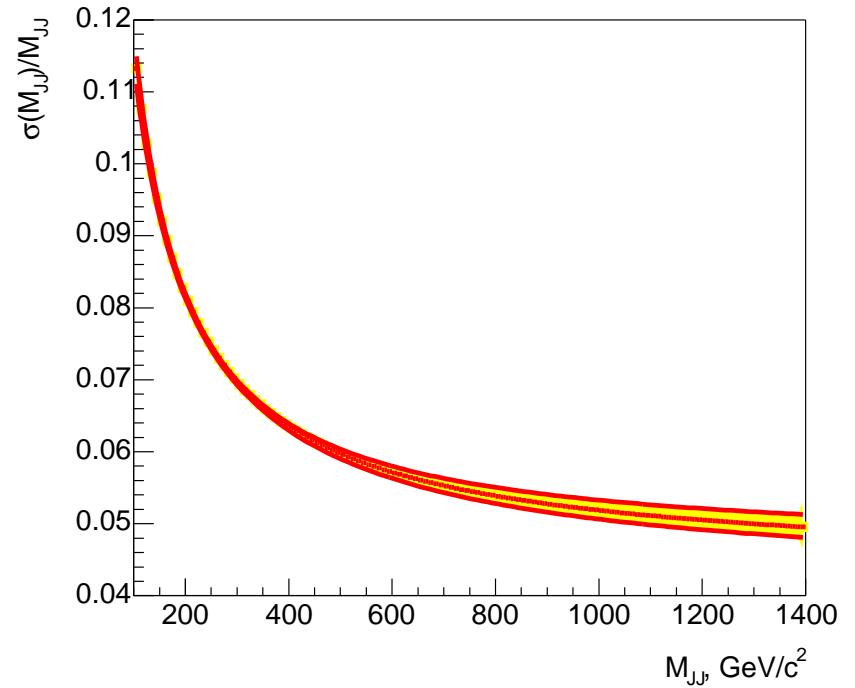
Dijet raw cross section ($\eta_{\max} < 0.5$)



Dijet mass resolution for $(\max(|\eta_{J1}|, |\eta_{J2}|) < 0.5)$

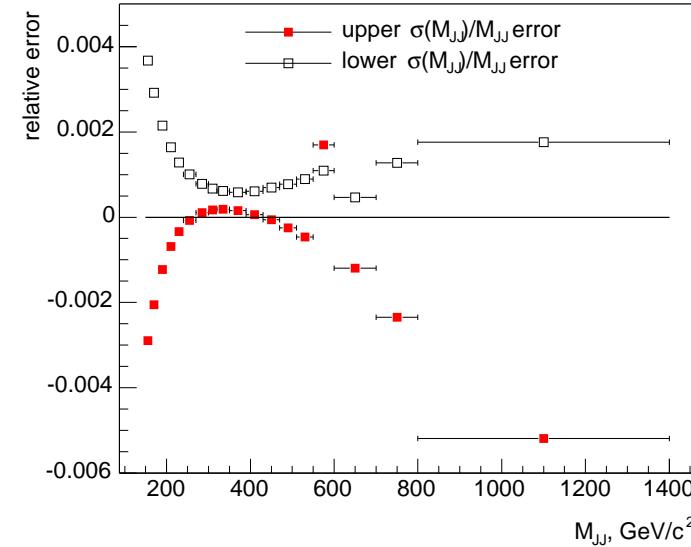
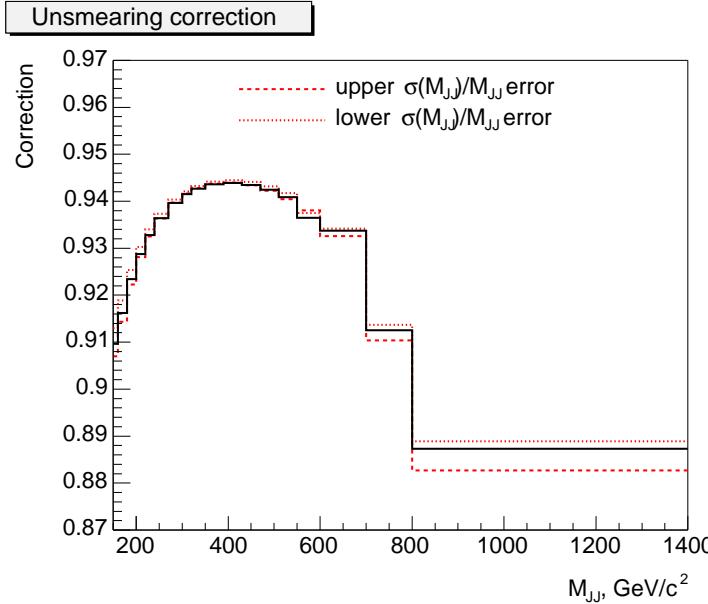


Dijet mass resolution for $(\max(|\eta_{J1}|, |\eta_{J2}|) < 0.5)$



$$\frac{\sigma M_{JJ}}{M_{JJ}} = \sqrt{\frac{N^2}{M_{JJ}^2} + \frac{S^2}{M_{JJ}} + C^2},$$

$$N = 6.4 \pm 0.7 \quad S = 0.87 \pm 0.03 \quad C = 0.0435 \pm 0.0008$$



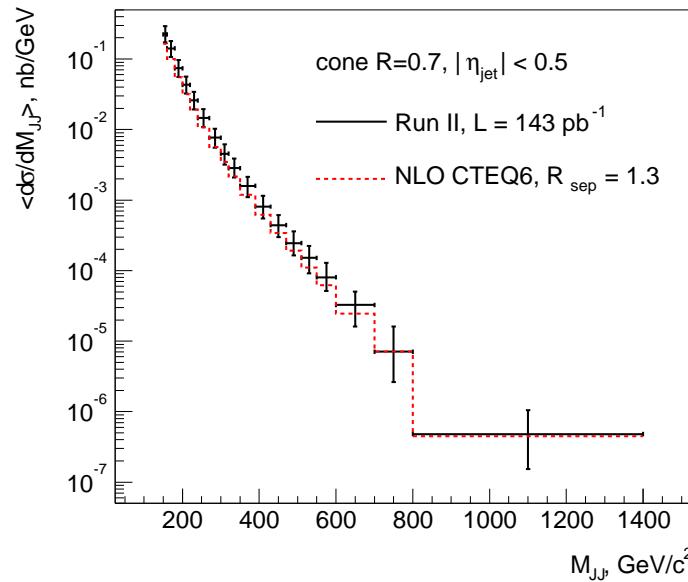
- ▶ fit cross section using ansatz function: $f(M_{JJ}|N, \alpha, \beta) = NM_{JJ}^{-\alpha} \left(1 - \frac{M_{JJ}}{\sqrt{s}}\right)^{\beta}$
- ▶ use dijet mass resolution for smearing:

$$F(M_{JJ}) = \int_0^{\sqrt{s}} dM'_{JJ} f(M'_{JJ}) G(M'_{JJ} - M_{JJ}, M'_{JJ})$$

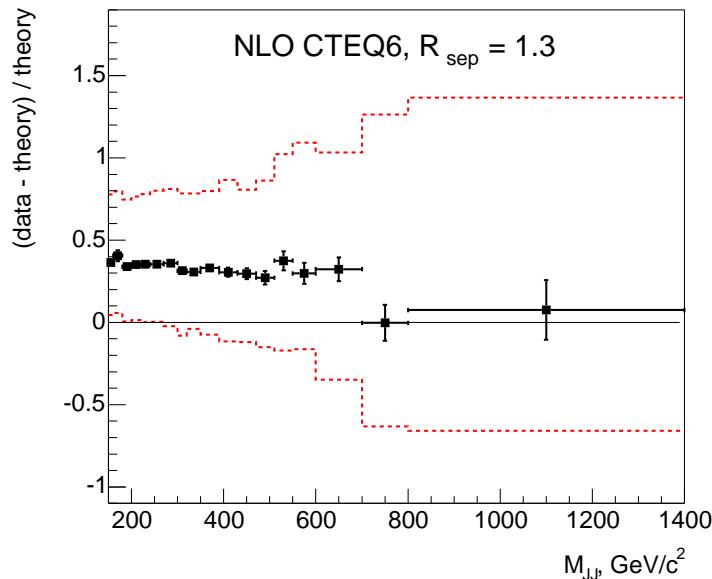
$$\text{▶ unsmeared correction: } C_{bin} = \frac{\int_{bin} dM_{JJ} f(M_{JJ})}{\int_{bin} dM_{JJ} F(M_{JJ})}$$

- ▶ systematic errors:

- ▶ uncertainty on jet p_T and ijet mass resolution
- ▶ different ansatz functions



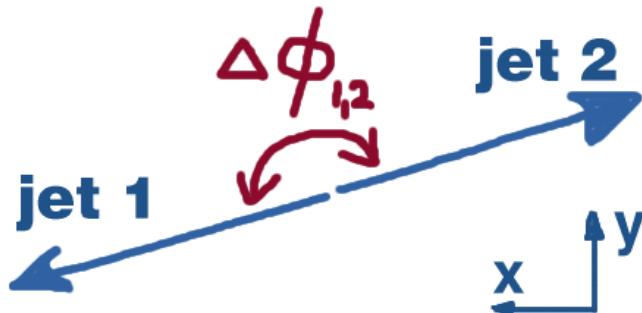
Data & theory comparison



- ▶ sources of systematic errors:
 - ▶ jet energy scale
 - ▶ unsmeearing
 - ▶ efficiencies
- ▶ dominated by jet energy scale error:
 - ▶ 150 – 160 GeV: +30 % –23 %
 - ▶ 800 – 1400 GeV: +120 % –68 %

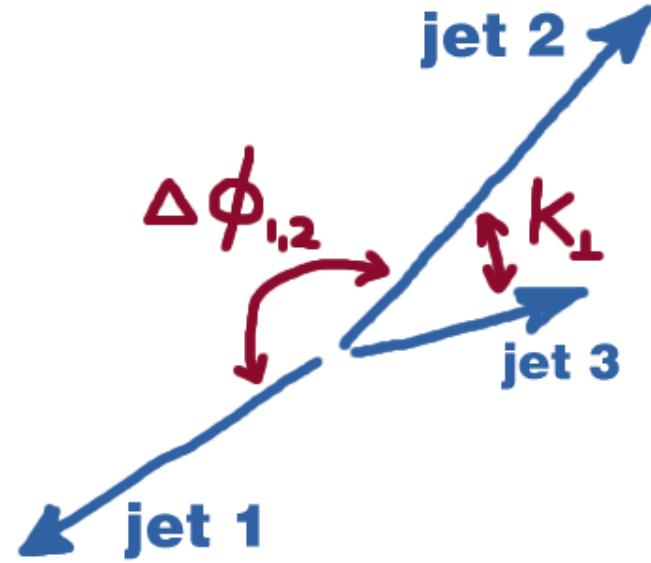
- ▶ $\Delta\varphi$ between two leading jets provides a clean laboratory for testing QCD
- ▶ simple to define and understand
- ▶ much easier to measure a jet's direction than its energy
- ▶ $\Delta\varphi$ distribution is directly sensitive to higher-order QCD radiation without explicitly measuring a third jet

Dijet production in lowest order pQCD:



$$p_T \text{ balance} \Rightarrow \Delta\varphi_{1,2} = \pi$$

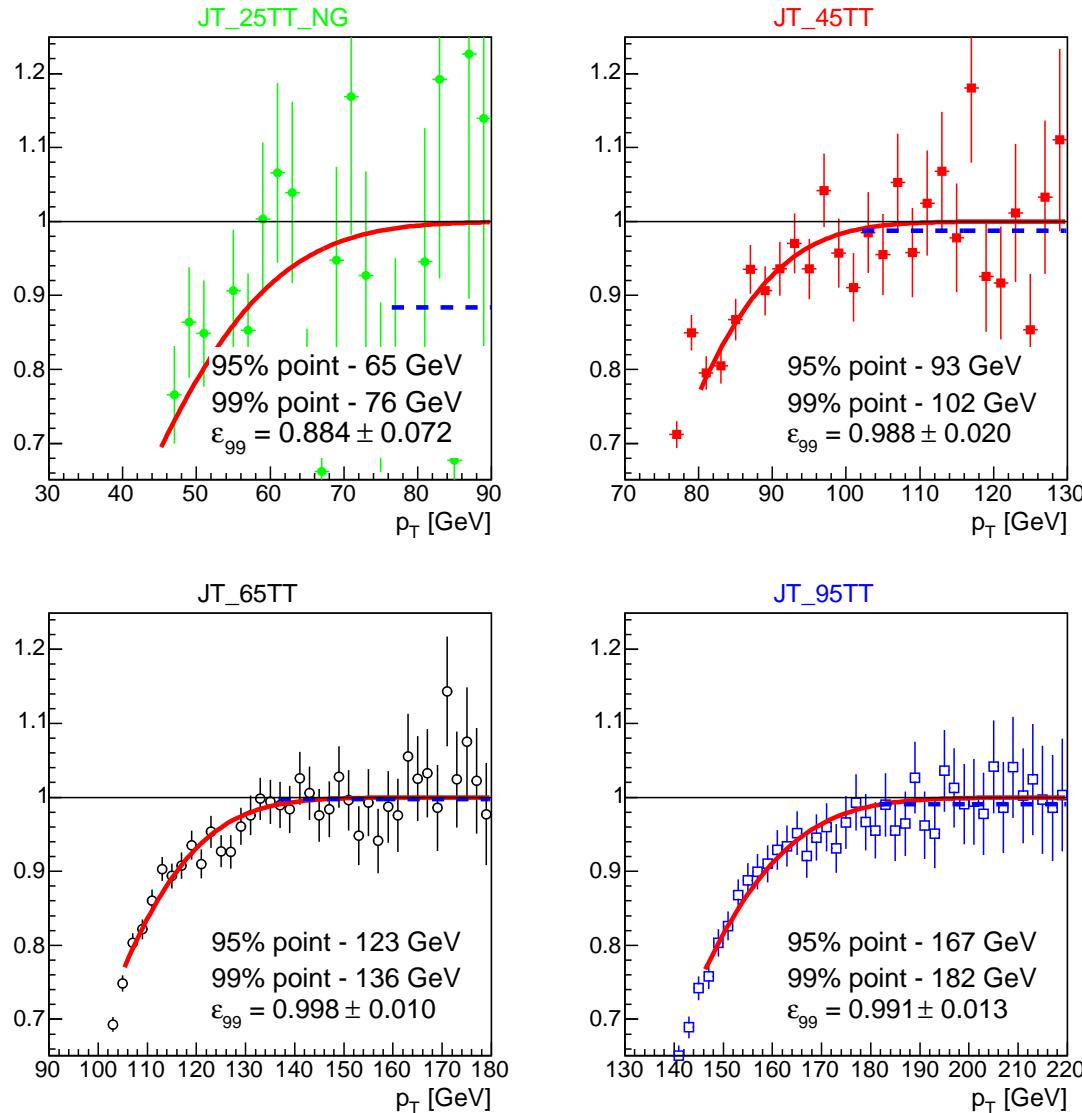
three-jet production in lowest order pQCD:



$$\text{hard third jet: } (k_\perp \text{ large}) \Rightarrow \Delta\varphi_{1,2} \ll \pi$$

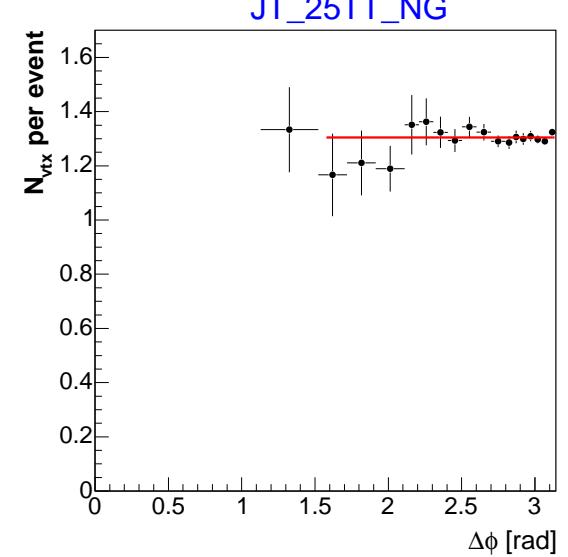
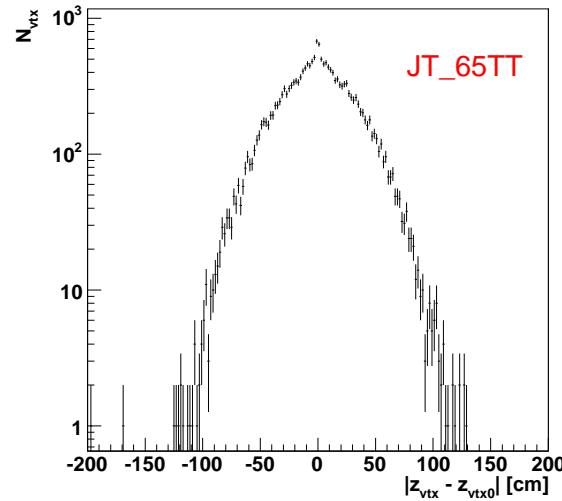
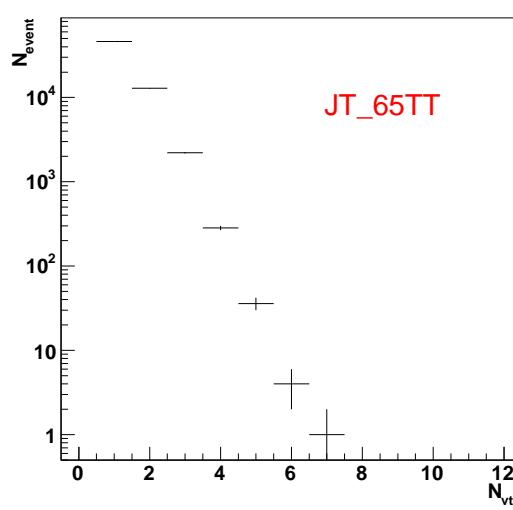
$$\begin{aligned} \text{soft third jet: (divergence in LO pQCD)} \\ (k_\perp \rightarrow 0) \Rightarrow \Delta\varphi_{1,2} \rightarrow \pi \end{aligned}$$

Trigger turn-on curves

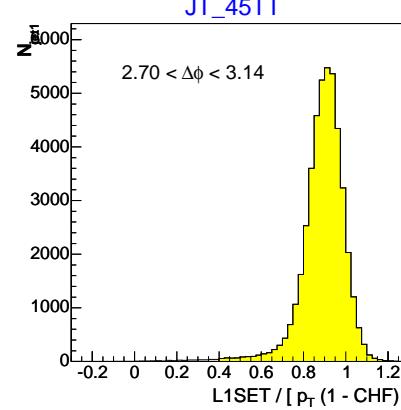
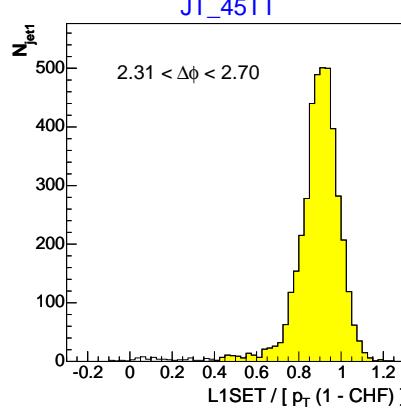
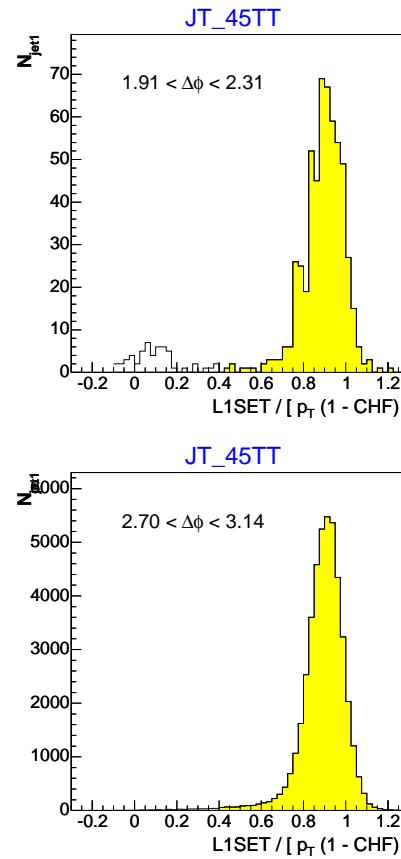
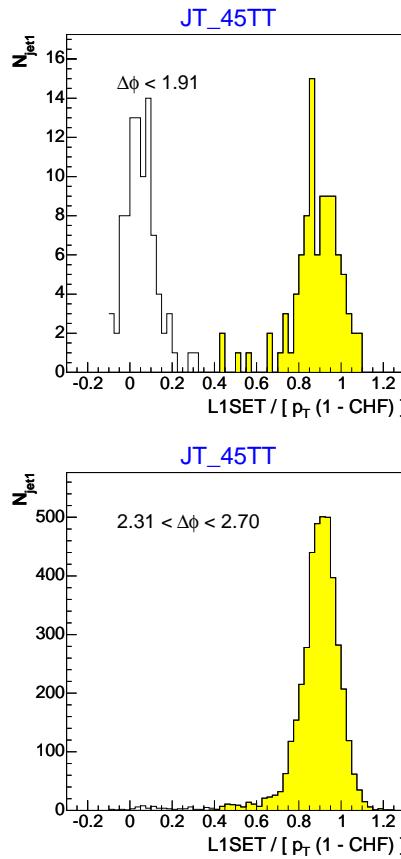


- ▶ relative turn-on curves
- ▶ ratio of the leading jets p_T spectra
- ▶ for events from the central dijet sample
- ▶ for rapidity $|y_{jet}| < 0.5$
- ▶ JES applied

Trigger	leading jet p_T , GeV/c
JT_25TT_NG	75 – 100
JT_45TT	100 – 130
JT_65TT	130 – 180
JT_95TT	> 180



- ▶ about 20 % of dijet events have at least two primary vertexes
- ▶ only small part (about 4 %) of them are duplicate vertexes
- ▶ the rest is coming from additional $p\bar{p}$ interactions
 \Rightarrow would be nice to check this number with expectation calculated from instantaneous luminosity
- ▶ $\Delta\phi$ is not directly sensitive to the vertex z coordinate
- ▶ no increase of vertex multiplicity observed for events at low $\Delta\phi$



- ▶ good separation between the background and signal
- ▶ the inefficiency of the cut seems to be very small
- ▶ purity of the sample is good



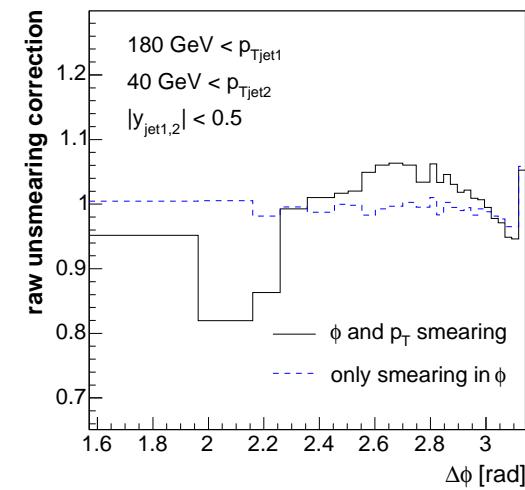
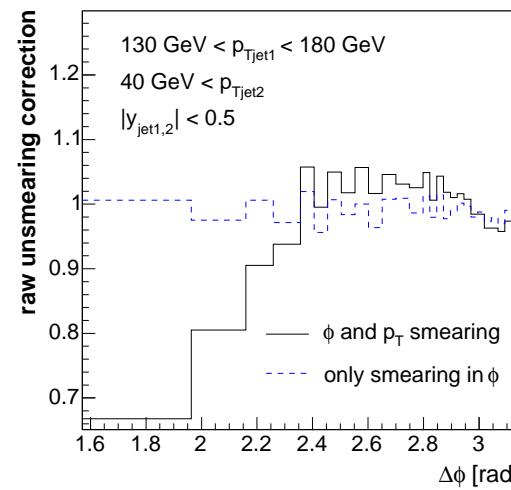
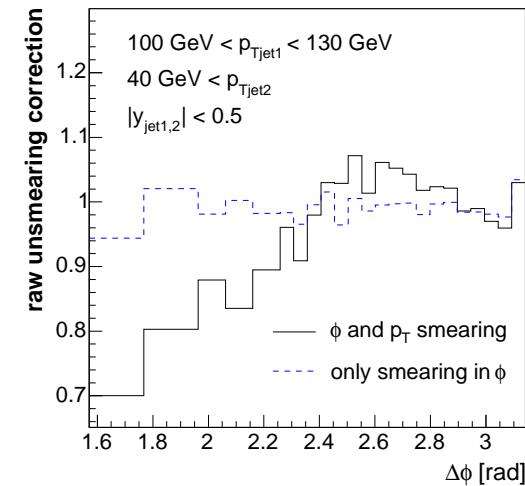
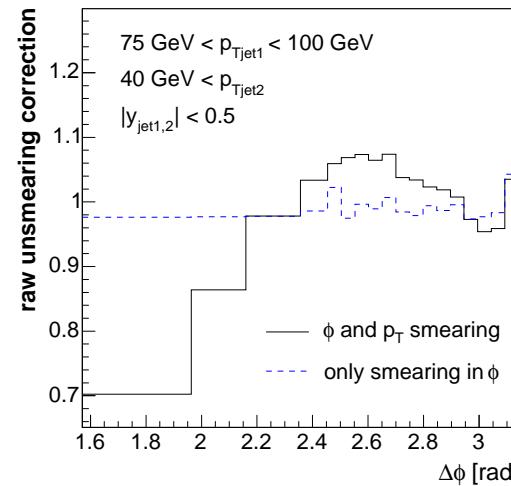
The $\Delta\varphi$ distribution

- dijet azimuthal angle defined as $\Delta\varphi = |\varphi_{jet1} - \varphi_{jet2}|$
- master formula for the $\Delta\varphi$ distribution

$$\frac{1}{N} \left\langle \frac{dN}{d\Delta\varphi} \right\rangle_{bin} = \frac{1}{\sum_{bins} C_i \tilde{N}_i} \cdot \frac{C_{bin} \tilde{N}_{bin}}{\Delta\varphi_{bin \ width}}$$

- $\Delta\varphi_{bin \ width}$ - $\Delta\varphi$ bin width
- \tilde{N}_{bin} - weighted sum of number of events
- C_{bin} - unfolding correction
- event weight w is given by the efficiency $w = 1/\varepsilon$
- the $\Delta\varphi$ distribution measured only for $\Delta\varphi > \pi/2$
 - to avoid region close to the $2R = 1.4$ limit (splitting/merging issues)
- bin size at $\Delta\varphi \sim \pi$ is roughly twice as expected resolution in $\Delta\varphi$

Unsmearing using toy MC

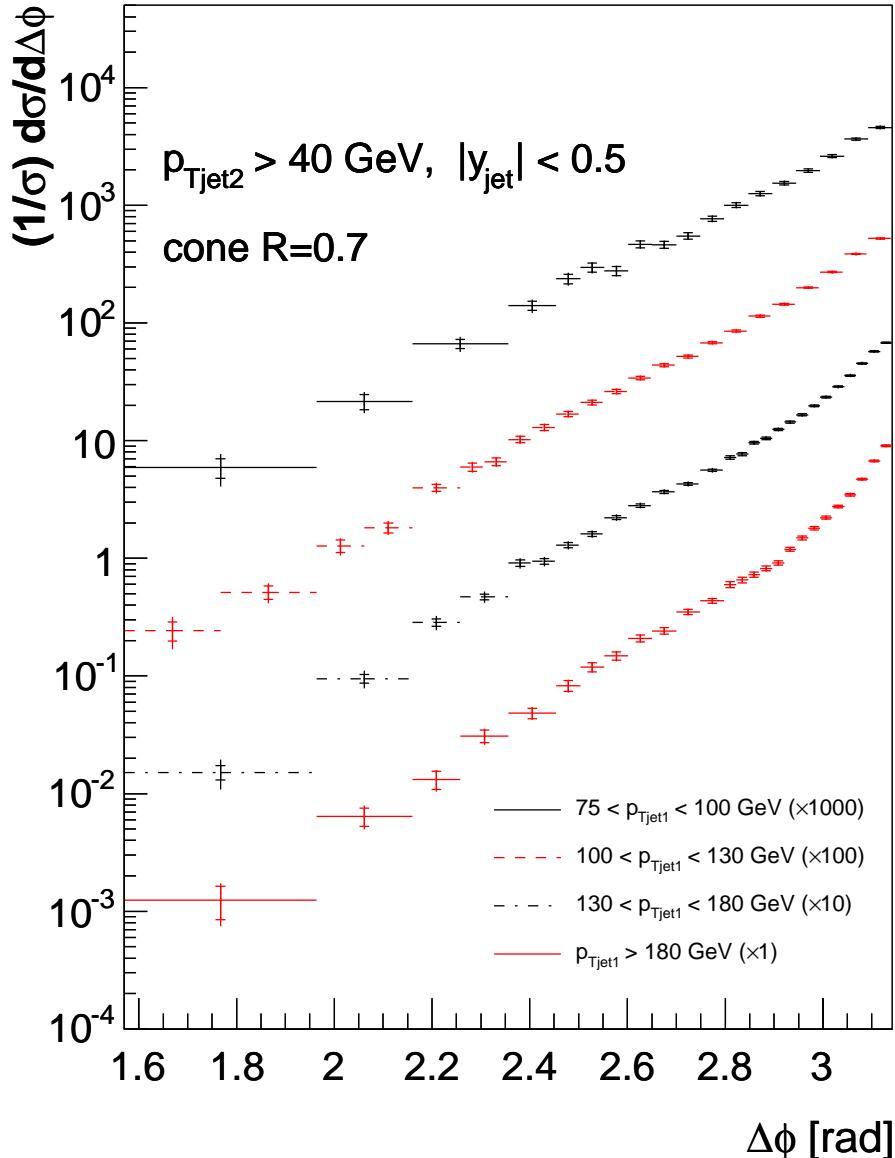


- ▶ resolution in ϕ important at $\Delta\phi \sim \pi$
- ▶ p_T resolution important in other regions of $\Delta\phi$



Unsmearing using toy MC

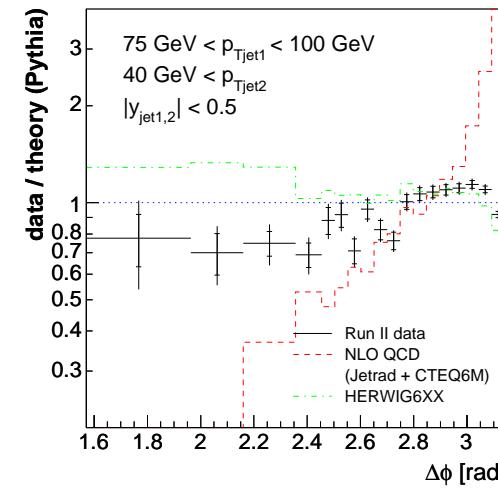
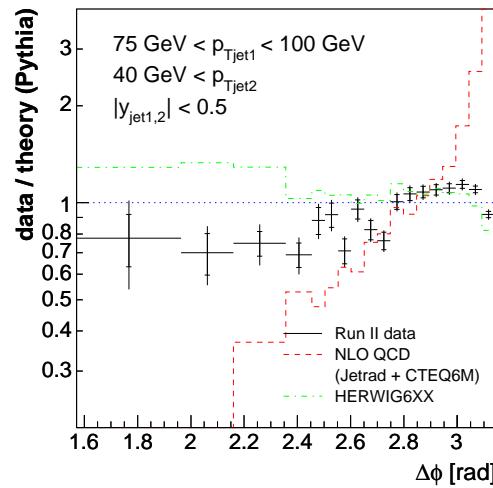
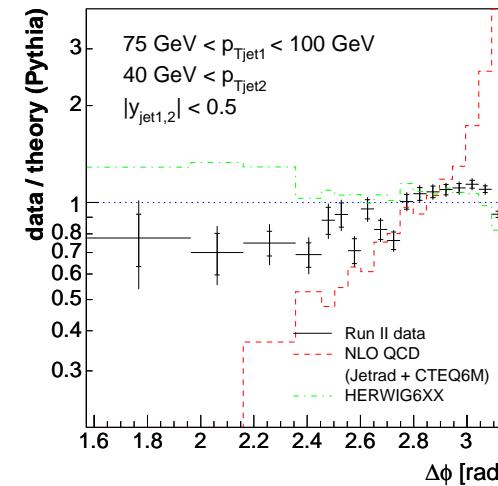
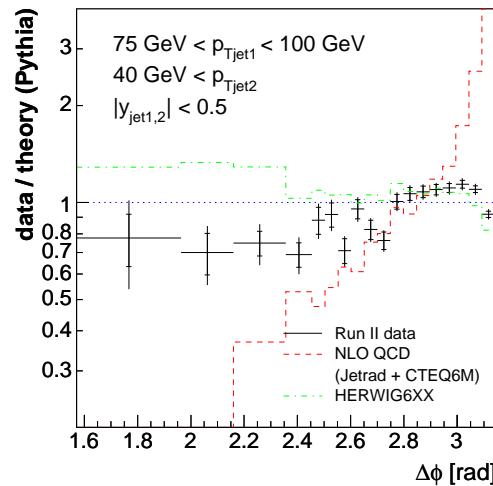
- ▶ Pythia 6.202 gives poor description of $\Delta\phi \Rightarrow$ reweighting needed



- ▶ statistical error - small horiz. bars
- ▶ systematic error - vertical bars
- ▶ change in the shape of the $\Delta\varphi$ distribution

leading jet p_T , GeV/c	Mean	RMS
75 – 100	2.956	0.173
100 – 130	2.965	0.177
130 – 180	3.011	0.134
> 180	3.033	0.117

Comparison with theory



- ▶ Jetrad normalized by σ_{NLO}
- ▶ Last bin at $\Delta\varphi \sim \pi$ is not correctly calculated for JETRAD



Summary

- ▶ Both dijet analysis are ready for Moriond
- ▶ Dijet mass measurement:
 - ▶ dijet mass distribution was measured for cone $R = 0.7$ jets in the central region of the calorimeter ($|y_{jet}| < 0.5$) using 143 pb^{-1} of the DØ Run II data
 - ▶ results agree within uncertainties with NLO QCD calculations
- ▶ Dijet $\Delta\varphi$ measurement:
 - ▶ $\Delta\varphi$ distribution was measured for cone $R = 0.7$ jets in the central region of the calorimeter ($|y_{jet}| < 0.5$) for four different bins of transverse momentum of the leading jet
 - ▶ as expected, $2 \rightarrow 2$ NLO pQCD calculation fails to describe the data in $\Delta\varphi \sim \pi$ and $\Delta\varphi < 2\pi/3$ regions
 - ▶ Pythia and Herwig, MC generators that models parton shower evolution, give better description of the data. However, the difference from the data is still significant



Notes for QCD group / DØ Collaboration

- ▶ Jet angular resolution in the central part of calorimeter for $R = 0.7$ cone, A. Kupco, P. Demine, C. Royon
- ▶ Measurement of dijet azimuthal angle distribution in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, A. Kupco, M. Begel, P. Demine, C. Royon, M. Wobisch
- ▶ Measurement of the dijet mass cross section, P. Demine, C. Royon
- ▶ the notes are located at
[http://www-d0.fnal.gov/Run2Physics/qcd/d0_private/agendas/
/current_meeting/notes_moriond2004/](http://www-d0.fnal.gov/Run2Physics/qcd/d0_private/agendas/current_meeting/notes_moriond2004/)